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MONETARY POLICY RULES IN A SMALL OPEN ECONOMY: AN APPLICATION TO MEXICO

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We estimate a small-scale macro model for the Mexican economy under the New Keynesian (NK) framework and alternative interest rate rules for Mexico. With these results we evaluate the performance of the Bank of Mexico against a set of optimality principles derived in the NK literature. Our system estimation results show that the Bank of Mexico holds a preference for stabilizing not only inflation around target, but also acts to achieve an output gap close to zero. Furthermore, we find that the central bank responds non-linearly to real exchange rate depreciations. We also find that the central bank has actively attempted to neutralize demand and supply shocks through monetary policy that is consistent with the Taylor principle.

JEL classifications codes: E52, E58
Key words: Taylor Rule, New Keynesian, monetary policy, interest rate rules, small open economy

I. Introduction

Price stability is an explicit objective of central bank policy in Mexico. In the past, monetary policy centered on the use of the exchange rate as the economy's nominal anchor, but when this resulted incompatible with macroeconomic conditions, the consequence often entailed a balance of payments crisis. Recently, Mexico's monetary policy has evolved towards the establishment of a precise inflation target, favoring

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the short-term nominal interest rate as policy instrument. Explicitly, the monetary authority aims to achieve the convergence of inflation to its target level in the medium-run; however, it is plausible that implicit additional objectives also guide policy. Hence, the comprehension of the factors to which the monetary authority responds, as well as the effect of policy decisions on the economy constitute a problem of interest. The effective identification of the transmission mechanism of monetary policy is a fundamental pillar of policy conduction.

The purpose of the present paper is to model the behavior of the Mexican economy and the response of the central bank to economic conditions during the past decade. We model the economic restrictions faced by policy-makers through a small-scale macro model in the New Keynesian (NK) tradition. This class of models incorporates nominal rigidities and imperfect competition into the dynamic stochastic general equilibrium (DSGE) framework developed in the Real Business Cycle (RBC) literature. The assumption of nominal rigidities generates a structure where monetary policy is effectively non-neutral in the short-run, while maintaining its long-run neutrality. We use this modeling strategy as a reference to determine which factors account in greater part for inflation dynamics in Mexico, as well as to determine important aspects of the transmission mechanism. Furthermore, we model the conduction of monetary policy as endogenous –with the short-run nominal interest rate as instrument– through the use of the monetary policy rule methodology.

This approach is attractive and has received plenty of attention in the literature. Its main strength lies in its capacity to systematically incorporate economic information in order to formulate a policy recommendation. Policy rules vary considerably in their essence and complexity, and can be broadly separated into simple and optimal rules. Simple interest rate rules tend to be characterized in the literature as linear functions of the inflation rate and the output gap. These rules are essentially ad hoc, although some baseline versions may be derived from standard theory as special cases.[1] However, their simplicity makes them an attractive initial step in the evaluation of monetary policy, as they are able to capture some important aspects of policy conduction. Conversely, optimal rules are the solution to the explicit optimization of an objective function, the latter of which may be utility, subject to the constraints imposed by the structure of the economy as a whole. By using a larger information set and by modeling interactions between variables in a more sophisticated manner, optimal rules contain a more rigorous analysis. However, their complexity may reach considerable levels, making the communication of policy objectives to the

[1] See, e.g., Clarida et al. (1999).

general public substantially more difficult. Simple policy rules are the focus of this paper because of their simplicity and capacity to describe actual policy.

We use a short-term nominal interest rate as policy instrument, reflecting the practice of major central banks. Although the Bank of Mexico only started to use this policy instrument in 2008, the previous one, namely the *corto*, may be interpreted as a signaling mechanism through which the central bank indicated its preference for the market interest rate structure. Following Torres (2002) and Roldán (2005), our analysis focuses exclusively on monetary policy rules for the determination of the short-run nominal interest rate.

We contrast two alternative policy rules and show that monetary policy in Mexico implicitly targets variables besides inflation, therefore operating under a “flexible” inflation targeting framework (IT). Under this regime, the central bank is additionally concerned with the evolution of macroeconomic variables besides inflation, and may pursue various goals simultaneously. In practice, it is reasonable to assume that central banks work towards achieving macroeconomic stability in a broad sense, assigning an important relative weight to price stability but not responding exclusively to it. The output gap and a measure of the exchange rate are among the additional variables targeted. Importantly, we show that the central bank’s response to exchange rate fluctuations is non linear, as previously modeled in the literature for Mexico. In fact, the analysis of a non-linear response to exchange rate fluctuations is imperative in order to square the interest rate rule with the facts. We then use our estimated results to evaluate policy against a set of optimality principles derived in the interest rate rule and NK literature. Our system estimation results suggest that the Bank of Mexico has established monetary policy as an effective nominal anchor, consistent with the Taylor principle, and that the Central Bank has in effect acted to stabilize inflation around its stated target, while at the same time responding to deviations in output and the real exchange rate from trend.[2]

The remainder of this paper is organized as follows. Section II introduces the macroeconomic model to be estimated. Section III presents a brief description of the data used in the exercise. Section IV carries out the estimation and presents some key results. Section V uses the econometric estimates of the key parameters

[2] An open debate remains on whether IT is sufficient for a central bank to avoid time-inconsistency. The greater transparency afforded by IT increases accountability of the central bank to the public, as argued by Svensson (2000) and Woodford (2000). This claim is disputed by another strand of the literature, arguing that additional institutional arrangements are required to ensure commitment to IT (Alesina and Stella, 2010). While the jury is still out on the issue, our work does not address the political economy of institutional arrangements needed to ensure commitment to IT.

of the model to perform an impulse-response analysis in the context of dynamic stochastic general equilibrium and compares the dynamics under alternative policy rules. Section VI concludes.

II. A small open economy model

The evaluation of alternative policy rules requires an analytic framework which is, as far as possible, concise and rich in the economic dynamics it is able to capture. Much of the recent literature on monetary policy employ models that bring imperfect competition and nominal rigidities into the DSGE structure developed in the RBC literature, yielding the NK literature. Because of the presence of nominal rigidities, monetary policy is non-neutral. Furthermore, the structure developed yields intuitive equilibrium conditions which are similar in structure to the IS-LM model.[3] Because of this, the NK framework is widely used in the rules literature.[4] The structure of this class of macroeconomic models, in its baseline case, is described by a system of equations composed by a demand curve and a supply curve, the latter characterized as a NK Phillips Curve (NKPC). The baseline model is expanded by Svensson (2000) and Galí and Monacelli (2005) to the analysis of the small open economy, explicitly formulating additional transmission mechanisms relevant to the small open economy. In particular, they highlight the role played by the real exchange rate. In the present paper, the model is closed with the inclusion of an interest rate rule to model the behavior of the central bank. The baseline model may be employed both in the evaluation of optimal rules as well as simple rules, the latter being the purpose of our paper. Each of the four relevant equations of the model, namely aggregate demand, aggregate supply, exchange rate dynamics, and the interest rate rule, is further discussed below.

The aggregate demand curve links financing conditions faced by agents with their consumption and investment decisions through time. This curve traditionally establishes a negative relationship between aggregate expenditure in the economy and the real interest rate, reflecting in part the endearment of debt as well as the decrease in the value of assets owned by agents. McCallum and Nelson (1997) show how a relation of this sort may be derived from the intertemporal utility maximization by a representative rational agent who chooses consumption and leisure subject to

[3] See, e.g., McCallum and Nelson (1997) for a complete discussion.

[4] See, e.g., Clarida, Galí and Gertler (1999), Svensson (2000), Woodford (2001), Galí and Monacelli (2005), Roldán (2005) and Moons et al. (2007).

a budget constraint. The aggregate demand curve is therefore given by the consumption Euler equation and the forward-looking consumption curve takes the form

$$c_t = a_1 r_t + a_2 E_t\left[c_{t+1}\right], \tag{1}$$

where c_t is consumption and $a_1 < 0$. Here, $E_t\left[\cdot\right] \equiv E\left[\cdot \middle| \Omega_t\right]$ is the expected value operator conditional on the information set Ω, known at time *t*. It is important to note that this form for the demand curve differs from its traditional version in the sense that future consumption is *not* determined by its present value. Rather, the expectation of future consumption determines consumption today.

Given that in the baseline model consumption represents the only source of demand in the economy, consumption demand equals aggregate demand. Furthermore, assuming that marginal cost is lower than the price set, producers supply *any* quantity demanded, so that aggregate demand equals output (Blanchard 2008). From these considerations, an aggregate demand equation is obtained as

$$y_t = a_1 r_t + a_2 E_t\left[y_{t+1}\right], \tag{1'}$$

where y_t is the output gap.

Following Roldán (2005) and Moons et al. (2007), it is important to note that a specification like the one shown in (1') may be augmented to take into account additional determinants of aggregate expenditure. First, it is important to note the explicit role played by the real exchange rate in a small open economy. Movements in this variable reflect movements in relative prices between two economies, which in turn have an impact on domestic demand and foreign demand for domestic goods. Because of this, it is desirable to explicitly include this variable in an aggregate demand relation for a small open economy like Mexico's. Second, it is desirable to include a term which captures the government's fiscal stance, since this may be in principle an important component of total demand in the economy. Finally, it is important to note that aggregate expenditure is not necessarily entirely forward-looking. In fact, it is reasonable to assume that consumption decisions are made in part in an adaptive manner, that is, they are backward-looking. This assumption may be theoretically justified on the grounds of a utility function which includes habit formation within its arguments. Alternatively, the backward-looking component can be justified on the grounds of asymmetric information among agents, so that, for some agents, their best guess about the future may be an extrapolation of the past. These considerations lead to a hybrid aggregate demand curve of the form

$$y_t = a_1 r_t + a_2 y_{t-1} + a_3 E_t\left[y_{t+1}\right] + a_4 q_t + a_5 g_t + a_6 y_t^* + \varepsilon_t^D, \qquad (2)$$

where q_t is a measure of the real exchange rate (an increase denotes a depreciation) which captures the effect of net exports on aggregate demand, g_t is a measure of the government's fiscal stance (a positive value denotes a fiscal deficit), y_t^* is a measure of the foreign output gap. The term ε_t^D is a stochastic error term which captures shocks to demand.

It is important to note that, although an aggregate demand curve as presented in (2) may provide a better fit when faced against the data by capturing economically relevant empirical correlations, the inclusion of ad hoc variables presents an important cost, as they turn the specification susceptible to the Lucas critique.[5] That is, in order to analyze a change in policy, one must estimate the "deep parameters" of the model, those that characterize agents' preferences and their possibilities of consumption and production. This path, however, entails substantial costs of its own, mainly in terms of explicative power in lack of a structural model for the economy. Therefore, estimation results pertaining to variables not explicitly derived from a micro-founded model should be interpreted with care, as it is possible that, facing a change in policy, the relations they describe may change too. Nonetheless, one may place greater confidence in the results pertaining to variables appearing in the fully specified theoretical model, such as the interest-rate elasticity of the output gap. Furthermore, it is important to note that the model presented will provide stronger results for short-run analysis.

Aggregate supply is modeled through a NKPC, which captures inflation dynamics in the economy, relating the change in prices with demand shifts, as reflected by the output gap, as well as pressure on prices stemming from agents' expectations. This relation can be derived in an environment of monopolistically-competing firms who seek to maximize profits, combined with the assumption of staggered price setting, as in Calvo (1983). The NK synthesis therefore allows the upholding of a theoretic framework of optimizing firms while at the same time deriving a positive relationship between inflation and real economic activity. In opposition to the traditional Phillips Curve, which is backward-looking in nature, the NKPC establishes that one of the main determinants of inflation is the expectation of future inflation, not its past realizations. Therefore, the NKPC takes the general form[6]

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[5] See Lucas (1976).

[6] A complete derivation is available in Galí and Monacelli (2005).

$$\pi_t^s = b_1 E_t\left[\pi_{t+1}^s\right] + b_2 y_t . \tag{3}$$

It is important to note that the inflation model describes underlying inflation.[7] This is due to the fact that underlying inflation better characterizes price responses to aggregate demand shocks. Non-underlying inflation tends to respond to seasonal variations or to shocks specific to a particular industry, rather than to aggregate shocks. Because of this, it is convenient to separately model both components of inflation. General inflation can then be recovered as the weighted average of both inflation measures.[8]

As in the case of the aggregate demand curve, for an empirical application it is convenient to augment the specification in order to explicitly take into account additional variables which may have a direct impact on inflation. First, it is important to note the role played by the exchange rate. Movements in this variable imply changes in the price of imported inputs for production. Hence, exchange rate depreciations have a direct impact on production costs, affecting domestic inflation. Foreign inflation, on the other hand, may be passed-through if there is not a one-for-one appreciation of the nominal exchange rate. Finally, the literature shows, as in Ramos Francia and Torres (2006), that inflation dynamics are better captured by a hybrid version of the NKPC, so the inclusion of a backward-looking component is desirable. This result recognizes that there may be learning effects, staggered contracts, or other institutional arrangements in the economy which might lead to a significant effect of past conditions, captured by lagged inflation, on current inflation. This leads to an augmented specification of the form

$$\pi_t^s = b_1 \pi_{t-1}^s + b_2 E_t\left[\pi_{t+1}^s\right] + b_3 y_t + b_4\left(\Delta e_t + \pi_t^*\right) + b_5 \Delta w_t + \varepsilon_t^S . \tag{4}$$

Here, e_t is the nominal exchange rate (again, an increase corresponds to a depreciation) and π_t^* is foreign inflation. The two variables have a significant effect on domestic inflation for a small open economy depending on how they affect the cost of imported intermediate goods used in the production process. They also impact the price of imported final goods, which affect CPI inflation. The term ε_t^S is a mean-zero stochastic term which captures aggregate supply shocks. As in the case of the aggregate demand curve, the augmented specification includes ad hoc

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[7] This definition of inflation is based on a price index which excludes goods with particularly volatile prices.

[8] The appropriate weighting coefficient is published by the Bank of Mexico.

terms which compliment the theoretically-derived structure. In particular, these components correspond, in addition to lagged inflation, to the “pass-through” term and the change in nominal wages. Roldán (2005) and Moons et al. (2007) employ similar specifications which compliment the theoretical model presented in Svensson (2000) and Galí and Monacelli (2005).

Given the role played by the exchange rate in both aggregate demand and supply in a small open economy, it is important to note some of the consequences of including this variable in the model. First, as noted by Svensson (2000), in an open economy the exchange rate is an important aspect of the transmission mechanism affecting aggregate demand, and eventually prices, through its impact on the trade balance. There is also, as mentioned before, a direct effect, as exchange rate movements affect the price of imported final goods, thus impacting CPI inflation directly. This channel, as pointed out by Svensson (2000), has a quicker effect on prices than the aggregate demand channel. Therefore, monetary policy may be faster to act on inflation in an open economy than in a closed one, as it acts through a greater variety of channels. Second, the exchange rate is essentially the price of an asset, so it is determined in a forward-looking manner. Because of this, the inclusion of the exchange rate contributes to the importance of forward-looking variables in the performance of the economy (Svensson, 2000). Finally, the exchange rate captures variations in foreign economic conditions such as inflation, interest rate movements, and country-risk premia. All these variables impact foreign demand for domestic goods, which will in turn affect domestic inflation. For these reasons, the class of macro models used in the monetary policy rules literature is enhanced by the inclusion of a specification that describes the behavior of the exchange rate. For this purpose, purchasing-power-parity (PPP) is invoked in order to express the (log) real exchange rate as

$$q_t = e_t + \left(p_t^* - p_t\right), \tag{5}$$

where p_t and p_t^* denote the level of domestic and foreign prices, respectively. It is assumed that uncovered interest rate parity (IRP) holds, so the real exchange rate can be expressed as

$$q_t = E_t\left[q_{t+1}\right] + \left(r_t^* - r_t\right), \tag{6}$$

where the real interest rate comes from an approximation to the Fisher equation of the form

$$r_t = i_t - E_t\left[\pi_{t+1}\right]. \tag{7}$$

However, empirical studies for industrial economies show that IRP does not hold in practice.[9] In particular, due to the fact that this is a condition of equilibrium, not behavior, the exchange rate shows systematic deviations from the level suggested by IRP. In fact, the exchange rate may "overshoot" after changes in the interest rate structure. In order to better characterize the behavior of the real exchange rate, therefore, it is convenient to use a more flexible specification, which allows a more gradual adjustment of this variable towards its long-run equilibrium level, identified by IRP:

$$q_t = \sum_{j=1}^{J} c_{1j} q_{t-j} + c_2 \left\{ E_t\left[q_{t+1}\right] + \left(r_t^* - r_t\right) \right\} + \varepsilon_t^q. \tag{8}$$

Roldán (2005) uses a specification of this type for the Mexican economy.

The macro model is closed with an interest rate rule that translates macroeconomic conditions into a policy stance. The canonical example of a simple monetary policy rule is the Taylor rule (Taylor 1993) that describes the level of the federal funds rate and establishes that it should be set at an assumed level for the equilibrium long-run nominal interest rate,[10] contingent to deviations of inflation from target and deviations of output from its potential level, approximated by a smooth trend. Clarida et al. (1999) show that a rule in the spirit of the Taylor rule may be derived from an optimization process in which the central bank minimizes a quadratic loss function (with deviations of inflation from target and the output gap as its arguments), subject to a standard NK macroeconomic model. In this sense, a simple rule may under certain assumptions, constitute an adequate approximation to optimal policy.[11] The interest rule derived by minimizing a quadratic loss function is, however, forward-looking. As such, it states that expected future deviations of inflation from target and future expected output gaps determine the path of the interest rate:

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[9] See, for example, Eichenbaum and Evans (1995).

[10] This rate is related to Wicksell's natural interest rate. See Wicksell (1907) for further details.

[11] In particular, it is necessary to assume that the output gap and real marginal costs are proportional. Additionally, a rule that implies a gradual adjustment of the policy instrument in response to real shocks is consistent with the minimization of loss derived from deviations of inflation from target as well as deviations of output from its potential level. These issues are further discussed in Clarida, Galí and Gertler (1999) and Woodford (2001).

$$i_t = \bar{i} + \varphi_\pi \left(E_t \left[\pi_{t+n} - \bar{\pi}_{t+n} \right] \right) + \varphi_y \left(E_t \left[y_{t+k} \right] \right). \tag{9}$$

Here, $\bar{\pi}_t$ denotes the central bank's inflation target, which may not be constant and presents a time subscript. Thus, monetary policy analysis through the rules methodology concentrates on examining the coefficients φ_π and φ_y, which imply the preferences of the central bank. Although simple, the Taylor rule incorporates some of the key results derived in the NK literature. Following a demand shock, both the inflation and the output gaps move in the same direction, which induces the corresponding move in the interest rate, thus neutralizing the demand shock. A supply shock, on the other hand, causes opposite movements in the inflation and output gaps. For example, a temporary negative productivity shock or a cost-push shock will lead to a rise in inflation, while the output gap will decrease. Therefore, the rise in the interest rate suggested by the rise in inflation will be roughly compensated by the decrease suggested by the contraction of output. In this sense, the interest rate will display only a muted response to the shock, consistent with New Keynesian optimality principles.[12] This rule may be written in terms of the real interest rate,[13] yielding

$$r_t = \bar{r} + (\varphi_\pi - 1)\left(E_t \left[\pi_{t+n} - \bar{\pi}_{t+n} \right] \right) + \varphi_y \left(E_t \left[y_{t+k} \right] \right). \tag{10}$$

Here $\varphi_\pi > 1$ is required in order to guarantee that the real interest rate rises when inflation is above target, thus allowing monetary policy to contract aggregate demand. Otherwise, that is if $\varphi_\pi < 1$, monetary policy cannot constitute the nominal anchor of the economy since it does not respond vigorously enough to nominal shocks, which may be persistent.[14] Torres (2002) presents estimations of this parameter for Mexico between 1997 and 2001, finding that monetary policy constituted an effective nominal anchor. Our analysis of simple rules is then centered on the performance of this rule within the specified macro model. With this purpose in mind, and based on principles previously discussed, a rule in the spirit of the Taylor Rule is proposed as

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[12] For a survey of the literature, see Clarida et al. (1999).

[13] See Torres (2002).

[14] The Taylor rule, as well as the methodology of interest rate rules in general, has faced sharp criticism in the literature. For a discussion of these issues and their resolution, see Woodford (2001) and Galí and Monacelli (2005).

$$i_t = (1-d_1)\left\{(d_2 + d_3\bar{\pi}_t) + d_4\left(E_t\left[\pi_{t+1} - \bar{\pi}_{t+1}\right]\right) + d_5\left(E_t\left[y_t\right]\right)\right\} + d_1 i_{t-1} + \varepsilon_t^i. \tag{11}$$

Torres (2002) uses a rule of this kind, as this specification allows for a nominal interest rate target which varies in time according to changes in the inflation target, as captured by the term $(d_2 + d_3\bar{\pi}_t)$. This fact is important given that the study encompasses a period of disinflation overseen by the Mexican central bank during the second half of the 1990s.

The simple interest rate rule is then evaluated against an augmented rule which considers real exchange rate depreciation within the central bank's reaction function. Even though Torres (2002) establishes that the inclusion of some measure of exchange rate depreciation does not improve the rule's fit, it is important to note that his work only considers a linear response from the monetary authority to movements in the exchange rate. The literature for industrial economies shows, as in Taylor, Peel and Sarno (2001) and Chinn (2008), that there may exist a non-linear response. Consequently, and differing from Torres (2002), we specify the augmented interest rate rule as

$$\begin{aligned} i_t = (1-d_1)\Big\{&(d_2 + d_3\bar{\pi}_t) + d_4\left(E_t\left[\pi_{t+1} - \bar{\pi}_{t+1}\right]\right) + d_5\left(E_t\left[y_t\right]\right) + d_6\left(E_t\left[q_{t+1}\right]\right) + \\ &d_7\left(E_t\left[q_{t+1}\right]^2\right) + d_8\left(E_t\left[q_{t+1}\right]^3\right)\Big\} + d_1 i_{t-1} + \varepsilon_t^i, \end{aligned} \tag{12}$$

where $E_t[q_{t+1}]$ is measured as the expected deviation of the real exchange rate around its long run trend. In this specification, the quadratic and cubic terms attempt to capture the non-linearity in the central bank's reaction function.[15]

To summarize, the macroeconomic model describing the economy with the simple interest rule is therefore given by the system of equations composed by (2), (4), (8) and (11), where the variables y, π^S, q and i are, respectively, the output gap, underlying inflation, real exchange rate and nominal interest rate. The variables y^*, π^*, r^*, are respectively output gap, inflation and real interest rate of the foreign country which is the US economy in this case. It is useful to describe some key connections in the system. The output gap given by equation (2) includes the real interest rate, r, which is defined as the nominal interest rate minus the expected inflation. Thus,

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[15] This specification implies a non-linear response of the interest rate to expected real exchange rate, measured as expected deviation from its trend. Specifically, the change in the interest rate following a change in the expected deviation will depend on the level of the expected deviation.

provided $a_1 < 0$, the output gap will be reduced by an increase in the nominal interest rate or higher inflation expectations. Equation (4) directly relates inflation with the output gap. Also, assuming the parity condition, the term $(\Delta e_t + \pi_t^*)$ is equal to $(\Delta q_t + \Delta \pi_t)$ so that higher real exchange rate implies higher inflation. The real exchange rate given by equation (8) includes the differential real interest rate term $(r_t^* - r_t)$ but we have defined $r_t = i_t - E_t\,[\pi_{t+1}^S]$ so that, provided $c_2 > 0$ as we expect to be the case, a higher nominal interest rate or lower expected inflation are associated with lower levels of the real exchange rate. Finally, for equation (11), as we expect all coefficients to be positive, the interest rate will be higher the higher are the inflation target $(\bar{\pi}_t)$, the expected deviations of inflation from target and the expected output gap. The degree of persistence of the interest rate process is given by d_1. For the augmented interest rule equation (11) will be substituted by equation (12). In this case, in addition to all previous relations, the interest rate will also depend on the expected real exchange rate. This will be an additional factor to influence the behavior of interest rates.

III. Data

This section briefly describes the data used for the estimation of the macroeconomic model. The short-run nominal interest rate under consideration is the 28-day CETES secondary market rate. Even though this is not the rate explicitly targeted by the central bank, it is assumed that the authority holds sway over this key market rate through its interest rate target scheme. The foreign short-run nominal interest rate is defined as the 4-week T-BILL secondary market rate.[16] The output gap is calculated from the log General Index of Economic Activity (IGAE), which is a monthly proxy for GDP. The gap is defined as the deviation of the index from its Hodrick-Prescott filtered trend. Similarly, the foreign output gap is calculated from the log U.S. Industrial Production Index (IPI). The bilateral real exchange rate between Mexico and the United States is calculated from the log nominal exchange rate as shown in (5).[17] The

[16] Due to the fact that there are no available data for this instrument for the first years of the sample studied, these are calculated as the 4-week rate implicit in 3-month Treasury bill rates. This calculation necessarily assumes that the expected monthly rate is the same through the three months to the bond's maturity. This assumption is reasonable for an economy with low levels of expected inflation and low inflation volatility, as is the case for the U.S. economy during the sample period.

[17] This measure of the exchange rate is used for the Mexican economy given that trade with the United States heavily dominates Mexico's current account. Price-level indexes for Mexico and the United States are transformed so as to represent an equal base year.

variable is expressed in terms of a deviation from its trend which is assumed to be quadratic. Underlying inflation is defined as the monthly change in the seasonally-adjusted underlying component of the log National Consumer Price Index (CPI). Non-underlying inflation corresponds to the monthly change in the non-underlying component of Mexico's log CPI. This component of inflation is modeled as exogenous due to the fact that underlying inflation better reflects pressure on prices stemming from shifts in aggregate demand. Non-underlying inflation captures price-changes in highly volatile goods and services whose prices respond to idiosyncratic shocks, which may not necessarily reflect pressure upon other prices in the economy. General domestic inflation is recovered as the weighted average of both components. Foreign general monthly inflation is measured as the monthly change in the log CPI for the U.S. Nominal wages are defined as the seasonally-adjusted change in the log nominal hourly wage in the manufacturing industry in Mexico, as reported by the National Institute of Statistics and Geography. The government's fiscal stance is defined as the change in a measure of government structural deficit, which measures variations in discretionary fiscal policy. This series is calculated from the government's deficit as in Cermeño, Roth and Villagómez (2008). Data are used in monthly frequencies, and correspond to the period following the Tequila crisis and its subsequent period of volatility. Thus, the sample encompasses 1998:01 to 2008:02. This period provides a sample suitable for the study of inflation dynamics under the IT regime, as well as a period for the analysis of exchange rate dynamics under a float.[18]

IV. Estimation of the macro model and interest rate rules

In this section we present system estimation results for the aggregate demand curve, the aggregate supply curve, the exchange rate relation and the interest rule. We have considered two sets of estimation results. One set includes equations (2), (4), (8) and (11) which considers the simple interest rule. The other set includes equations

[18] The sample period was chosen on the basis of availability of data for all needed variables. It is important to point out, though, that in the third and fourth quarters of our initial year (1998) Mexico, as many other economies, was hit by the Russian financial crisis and at that time the short term interest rate in México increased substantially basically due to an increase in risk premia. Episodes like this may challenge the robustness of our results as our model does not include explicitly a risk premium factor. In our model these episodes will only be captured as non-persistent exogenous shocks to the interest rate. Reducing the sample period as to exclude the Russian crisis would not be convenient given that it will shorten considerably the sample length, and still will not address the risk premium issue. This matter is beyond the scope of the present research and needs further investigation.

(2), (4), (8) and (12), and corresponds to the augmented interest rule. Both systems have been estimated by the Generalized Method of Moments (GMM).

For models including terms such as $E_t[y_{t+1}]$, there are two options for econometric estimation. The first approach consists of solving the model using information on its structure such that the expectations are expressed only in terms of observable variables and then proceed with the econometric estimation. The second approach uses the fact that, by definition, the realized (ex-post) value of any variable equals its expected value plus a forecast error, namely $y_{t+1} = E_t[y_{t+1}] + \varepsilon_{t+1}$. Thus when we use realized ex-post values we are introducing terms like $E_t[y_{t+1}] = (y_{t+1} - \varepsilon_{t+1})$ in the right hand side of the equation and generating endogeneity by construction between y_{t+1} and ε_{t+1}, which will form part of the residual. In this context, instrumental variable methods would be consistent but not efficient since they ignore the fact that all equations are related and the same applies to single equation GMM estimation. A fully efficient method would then be the system GMM estimator.

In this paper we will adopt the second approach. Given that the equations describing the dynamics of the economy include forward-looking variables, which are measured by their realized ex-post values, it is not possible to use Least Squares methods since in this context there is endogeneity by construction.[19] Specifically, as is well known in the literature on estimation of rational expectations models, when using ex-post values of non-predetermined variables instead of their ex-ante or expected values, the overall error term in the equation becomes a linear combination of an exogenous shock and the forecast error of the forward-looking variables, which will be correlated with the ex-post values included in the right hand side of the equation. As we said before, in this context, the use of single equation instrumental variable methods, such as two-stage least squares, will be consistent but not efficient.[20] Because of these considerations, and following the related literature, the previous systems will be estimated by GMM techniques using past values of predetermined

[19] It is important to note that, in principle, it should be possible to use data on expectations of agents about these variables (this is particularly true in the case of inflation expectations, on which periodic surveys are conducted). However, as pointed out by Torres (2002), the use of these measures may bring about problems in its own right, particularly if the expectations of agents are systematically different from those held by the central bank, the later being the relevant set in the formulation of policy. In the case of inflation expectations reported by professional forecasters, for example, it is essential to note that forecasters face asymmetric costs for under-forecasting and over-forecasting inflation, which may lead to a systematic forecast bias. Additionally, it is necessary to recognize that there are no available explicit measures for agent's expectations of variables such as the output gap or the real exchange rate.

[20] See, for example, Maddala (2001).

and non predetermined variables as instruments in order to obtain a set of orthogonal restrictions which guarantee zero correlation between the right hand side variables and the error terms in each equation. System estimation is necessary in order to take into account the likely cross correlation among the different equations of the macro model, thus making the system GMM estimator, unbiased and fully efficient.[21] With these considerations in mind, the four equations describing the dynamics of the economy have been estimated.[22] Table 1 presents estimation results for the system with the simple interest rule.[23]

Results for the aggregate demand equation appear in the first column of Table 1. We can point out some interesting results. First, the coefficient corresponding to the elasticity of the output gap to the real interest rate is negative, as predicted by theory. Also this coefficient is statistically significant at the 1% level and its magnitude lies within the range estimated for other small open economies.[24] Second, both the one-period lag and one-period lead of the output gap are statistically significant and present the expected sign. This outcome is consistent with the literature which estimates hybrid aggregate demand equations, both for developed and developing economies. Additionally, the magnitude of the estimated coefficients is worthy of note, as they suggest that the lead of the output gap has higher weight than the lag in the determination of the output gap.[25] The real exchange rate reports the expected positive sign, as real exchange rate depreciations, reflected by a rise in q_t, should stimulate foreign demand for domestically-produced goods. The positive and

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[21] Beyond this econometric justification, Favero and Rovelli (2002) argue that estimation of an interest-rate rule in a single-equation specification is not advisable, except if the researcher is only interested in the behaviour of the coefficient associated to the gap between expected and target inflation. These authors recommend estimation of a system of equations, allowing for the possibility to retrieve the structural parameters associated to the preferences of the monetary authority and the structure of the economy. A related study for the case of Canada is Rodriguez (2006).

[22] The system has been estimated in unrestricted form. Concretely, the dynamic homogeneity restrictions that the dynamic coefficients must add up to one has not been imposed. Nonetheless, the unrestricted estimates add up to a number close to one. However, for the impulse-response analysis, given in Section 6, the dynamic homogeneity conditions are satisfied and this ensures that the impulse-response functions are unbiased.

[23] Interpretation of the results should be taken with care given that we are implicitly imposing a "ceteris paribus" assumption on the dynamics of all processes and our estimates may be subject to the Lucas' critique.

[24] See, for example, Moons et al. (2007).

[25] The Wald test for the equality of both coefficients takes the value of 38.96 thus rejecting this hypothesis.

Table 1. GMM system estimation results for model with simple Taylor rule

Aggregate demand: y		Aggregate supply: π^s		Real exchange rate: q		Simple interest rule: i	
a_1	-0.016***	b_1	0.488***	c_{11}	0.393***	d_1	0.772***
	(0.003)		(0.009)		(0.009)		(0.005)
a_2	0.289***	b_2	0.4922***	c_{12}	-0.036**	d_2	0.016***
	(0.014)		(0.007)		(0.015)		(0.001)
a_3	0.437***	b_3	0.004***	c_{13}	-0.103***	d_3	1.339***
	(0.020)		(0.001)		(0.016)		(0.016)
a_4	4.0E-04***	b_4	4.0E-04***	c_{14}	0.057***	d_4	1.861***
	(0.000)		(0.000)		(0.009)		(0.044)
a_5	4.5E-06***	b_5	9.0E-04***	c_2	0.689***	d_5	0.920***
	(0.000)		(0.000)		(0.005)		(0.066)
a_6	0.243***						
	(0.026)						
Adj. R^2	0.63		0.93		0.95		0.92
Reg. s. e.	0.0084		0.0010		0.0140		0.0197
Sum $\hat{u}^2$	0.0080		0.0001		0.0231		0.0448
Instruments:	$\Delta y_{t-j}, r_{t-j}, \Delta y^*_{t-j}$		$\pi^s_{t-j}, \Delta y_{t-j}, \Delta e_{t-j}, \Delta w_{t-j}$		$E_{t-j}[q_{t-j+1}] + (r^*_{t-j} - r_{t-j})$, $q_{t-h}, \Delta y_{t-j}$		$E_{t-j}[y_{t-j+1}], i_{t-k}$ $E_{t-j}[\pi_{t-j+1} - \bar{\pi}_{t-j+1}]$
Determinant residual covariance: 4.04E-18; J-statistic: 0.9810							

Values in parenthesis are standard errors. All equations include a constant term as instrument. The indexes for the instruments are: $j = 1,\ldots,12$; $h = 6,\ldots12$; $k = 2,\ldots,12$.

statistically significant, albeit small, value of this coefficient suggests that the Marshall-Lerner condition is satisfied, so that demand for export goods is sufficiently elastic and depreciation has a positive net effect on the trade balance. The variable representing the government's fiscal stance proves to be statistically significant and positive, although it has a relatively small value. Finally, foreign demand seems to play an important role in the determination of Mexico's output, as seen by the correlations between Mexico's output gap and its U.S. counterpart, Mexico's chief international trade partner.

Results for the aggregate supply curve are presented in the second column of Table 1. First, the coefficients on the lagged dependent variable and its expectation are statistically equal.[26] This result points to the conclusion that the behavior of

[26] The Wald test for the equality of these two coefficients equals 0.08, which is not significant at any conventional level and cannot reject this hypothesis.

underlying inflation is equally inertial or backward looking as it is forward looking. However, there are other variables which significantly correlate with inflation. Concretely, the output gap coefficient shows the expected positive sign. An increase in the output gap in the previous period reflects excess aggregate demand, which puts upward pressure on prices in the economy in this period. On the other hand, it is interesting to note that, even though there is a statistically significant and positive pass-through effect of foreign inflation on underlying CPI inflation in Mexico, it is remarkably small. This result is in line with studies which suggest that this factor has lost relative importance as a driver of inflation in Mexico. Similarly, changes in nominal wages appear to explain inflation during this period as we obtain a positive and statistically significant coefficient, although it is also remarkably small.

The estimation results for the exchange rate equation are shown in the third column of Table 1. In this case, it is interesting to note that the coefficient on the interest rate parity condition is positive and statistically significant. The data suggests that the exchange rate channel (assuming that there is a movement in the real exchange rate) is relevant in a small open economy like Mexico's. Furthermore, lagged values of the real exchange rate also contain useful information about its current value. The results obtained suggest that, in agreement with the empirical literature, the real exchange rate shows persistence, although it contains an important forward-looking element. Thus, the interest rate parity condition should be interpreted as a long-run equilibrium condition, but there may be temporary deviations from this equilibrium level in the short and medium run.

Estimation results for the central bank's policy reaction function, under the simple interest rate rule, are shown in the fourth column of Table 1. These results indicate that there is effectively an important inertial component in the determination of the interest rate, as reflected in the relatively high value of d_1. This obeys to the fact that the most frequent policy decision is to maintain the interest rate target unchanged. On the other hand, it is important to note that the coefficient d_4, corresponding to the weight assigned by the central bank to deviations of inflation from target, is positive and statistically significant. Moreover, the estimated coefficient is statistically greater than unity.[27] This result is consistent with a monetary policy sufficiently aggressive to maintain prices anchored. Additionally, it is interesting to note that the coefficient pertaining to the output gap, d_5, is likewise positive and statistically significant. This suggests that the central bank assigns a positive weight to the behavior of real economic

[27] The Wald test of the null hypothesis that $d_4 = 1$ against the alternative that $d_4 > 1$ equals 380, thus strongly rejecting the null at the 1% significance level.

activity when formulating policy. These initial results seem to corroborate the hypothesis that the Mexican central bank operates under a flexible inflation targeting framework, where both nominal and real variables are target variables.[28]

As we argued in the previous section, it is likely, though, that the Bank of Mexico will take into account the expected real exchange rate to decide on monetary policy. In what follows we explore this possibility by estimating the system with the augmented interest rule, which explicitly considers the exchange rate within the central bank policy reaction function, given by equation (12). In Table 2 we present the results.

Table 2. GMM system estimation results for model with augmented Taylor rule

Aggregate demand: y		Aggregate supply: π^s		Real exchange rate: q		Augmented rule: i	
a_1	-0.015***	b_1	0.487***	c_{11}	0.40***	d_1	0.753***
	(0.003)		(0.008)		(0.008)		(0.005)
a_2	0.287***	b_2	0.492***	c_{12}	-0.045***	d_2	0.012***
	(0.012)		(0.006)		(0.011)		(0.001)
a_3	0.442***	b_3	0.004***	c_{13}	-0.093***	d_3	1.145***
	(0.017)		(0.001)		(0.010)		(0.014)
a_4	3.0E-04***	b_4	4.0E-04***	c_{14}	0.054***	d_4	1.181***
	(0.000)		(0.000)		(0.006)		(0.051)
a_5	4.7E-05***	b_5	0.001***	c_2	0.69***	d_5	0.63***
	(0.000)		(0.000)		(0.005)		(0.062)
a_6	0.242***					d_6	0.225***
	(0.023)						(0.017)
						d_7	8.553***
							(0.233)
						d_8	44.051***
							(2.134)
Adj. R^2	0.63		0.93		0.95		0.94
Reg. s. e.	0.0084		0.0010		0.0141		0.0169
Sum $\hat{u}^2$	0.0080		0.0001		0.0231		0.0321
Instruments:	$\Delta y_{t-j}, r_{t-j}, \Delta y^*_{t-j}$		$\pi^s_{t-j}, \Delta y_{t-j}, \Delta e_{t-j}, \Delta w_{t-j}$		$E_{t-j}[q_{t-j+1}]+(r^*_{t-j}-r_{t-j})$, $q_{t-h}, \Delta y_{t-j}$		$E_{t-j}[y_{t-j+1}], i_{t-k}$ $E_{t-j}[\pi_{t-j+1}-\bar{\pi}_{t-j+1}]$
Determinant residual covariance: 2.43E-18; J-statistic: 0.9893							

Values in parenthesis are standard errors. All equations include a constant term as instrument. The indexes for the instruments are: $j = 1,\ldots,12$; $h = 6,\ldots 12$; $k = 2,\ldots,12$.

[28] However, it is important to consider the result that even if the output gap is not an objective in the central bank's loss function, there might be a significant coefficient for it in the interest rate rule. See, for example, Clarida, Galí and Gertler (1999).

The first striking result is that the estimation results for the aggregate demand, aggregate supply and exchange rate dynamics are virtually the same as the ones previously reported for the case of the simple policy rule. Therefore, in what follows we will only focus on the results obtained for the augmented interest rule equation and the contrasting of the two alternative systems to determine the one that best fits the data. First of all, the estimated degree of interest rate inertia in the rule, coefficient d_1 is equal to 0.75 which is virtually quite close to the one obtained for the system with the simple interest rule (0.77). Second, although the coefficient d_4, which measures the response to deviations of inflation from target, is numerically lower than the one obtained in the case of the simple interest rate rule, it is still significantly greater than one.[29] As far as the relative weight that this augmented interest rule assigns to the output gap, measured by d_5, we obtain a positive and statistically significant coefficient, although lower than the one obtained with the simple interest rule. These results suggest a central bank's response to deviations of inflation from target as well as deviations of output from its potential level. In particular, the estimation of the augmented rule confirms the key result obtained from the estimation of the simple rule. Concretely, both estimations are consistent with aggressiveness in the conduction of the monetary policy. It is worth noting that the literature for Mexico presents opposing results with which to compare this outcome. While Torres (2002) finds a coefficient for deviations of inflation from target statistically greater than unity, Galindo and Guerrero (2003) do not obtain this result.

With regard to the estimated response of the central bank to movements in the real exchange rate, measured as a deviation from its trend, it is found that the coefficients in the linear, quadratic and cubic terms in the real exchange rate are all positive and statistically significant, thus suggesting that the central bank will unambiguously tighten its monetary policy as the currency weakens (peso depreciation) and the real exchange rate is above its long run trend. More importantly, the previous results support the hypothesis that the central bank's response is non linear implying that the authority aggressively responds to large positive deviations of the exchange rate with respect to its trend, which in practice may be a long-run equilibrium level. Taken a as whole, the results for the augmented interest rate rule strongly suggest that the monetary authority is in fact concerned with maintaining not only price stability but also exchange rate stability through a monetary policy particularly aggressive when the peso weakens relative to its long run trend.

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[29] In this case, the Wald test of the null hypothesis that $d_4 = 1$ against the alternative that $d_4 > 1$ equals 12.5 and also rejects the null at the 1% significance level.

Finally, before presenting the dynamics of the macro models, it is important to determine econometrically which of the rules best fits the data. Given that both models, i.e., the systems with simple and augmented interest rules, are nested, we conduct three tests. The first one is a likelihood ratio (LR) test based on the values of the determinant of the residual covariance matrices from both systems. Secondly, we perform a Wald test (W1) on the system with the augmented rule in order to determine whether the real exchange rate terms in the augmented interest rule are jointly significant. The third test is also a Wald test (W2) of the restriction that the nonlinear terms of the real exchange rate in the augmented interest rule equation are zero. In the first two cases, the test will have a chi-square distribution with three degrees of freedom and, if it is significant, the restriction that the coefficients on the real exchange rate in the augmented interest rule are jointly zero will be rejected, validating the system with the augmented interest rule. In the last case, the test will have a chi-square distribution with two degrees of freedom and if it proves significant, the central bank's response to exchange rate will be nonlinear, otherwise the response will be linear. We have obtained the values $LR = 62.02$, $W1 = 3370.68$ and $W2 = 1768.12$, which are all statistically significant and strongly reject the said null hypotheses, leading to the unambiguous conclusion that the central bank behavior takes into account the real exchange rate and that its responses are non linear. Therefore, the system with the augmented interest rule, given by equations (2), (4), (8) and (12), is preferred.

V. Model dynamics under alternative interest rate rules

In this section, we evaluate the dynamics of the macro model through an impulse-response analysis. Specifically, we use the econometric estimates to solve the macro model in the context of dynamic stochastic general equilibrium and evaluate the dynamics of adjustment of the endogenous variables to exogenous shocks.[30] In this exercise, we focus on the effects of shocks to aggregate demand and aggregate supply under the two alternative policy rules. The shocks are modeled without persistence (as they are modeled in the paper) and with covariance matrix equal to the residual covariance matrix estimated econometrically.[31]

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[30] The econometric estimates used to solve the model were rounded to three decimal digits and whenever they were too small, we gave them the value of 0.001. We used the package DYNARE 4.1.3 available at http://www.dynare.org. A useful source for this package is Stéphane Adjemian, et al. (2011).

[31] It is important to remark that the impulse-response functions are not derived from an econometric exercise such as in VAR analysis. Instead, they are obtained from solving the small macro models (with

The NK literature provides a reference of principles on which sound monetary policy should rest in order to control inflation in the medium run. Clarida et al. (1999) survey the literature and point to the main results derived, of which key consensus points are worthy of note. (i) Under optimal policy, when facing a rise in expected inflation, nominal interest rates should increase sufficiently to elevate real rates. (ii) An optimal policy requires modifying the interest rate in order to fully neutralize demand shocks. Given that output in the long run is determined by supply-side factors, any excess demand will lead to an excessively high price level without a corresponding increase in output in the long run. Additionally, the increase in the price level derived from excess aggregate demand may become persistent if expectations of high future inflation are established. (iii) When facing shocks to potential output, or supply-side shocks, interest rates should not be modified under optimal policy. In this case, for example, a negative supply shock will lead to a one-off increase in inflation, reflecting a change in relative prices. If inflation expectations remain unaffected, inflation will return to its former level in subsequent periods. These principles provide a framework against which to evaluate the modeled response of the Central Bank to shocks.

Figure 1, panel A, shows the impulse-response functions to an orthogonal demand shock under the policy dictated by the simple interest rate rule. The shock causes the output gap to increase temporarily, prompting a drastic rise in the nominal interest rate. The process is accompanied by an exchange rate appreciation, which further reinforces the restrictive policy to neutralize the shock. Although inflation initially drops it cannot be prevented from rising above its steady-state level, reaching its peak approximately at period five. The central bank increases further the interest rate, above its steady-state level, in the first few periods following the shock and then decreases it gradually. At the same time, the appreciated real exchange rate gradually returns to its steady-state level. Overall, the central bank keeps a restrictive policy, which is somehow reinforced by the appreciation of the real exchange rate and its behavior is consistent with consensus points of sound monetary policy when facing shocks to aggregate demand.

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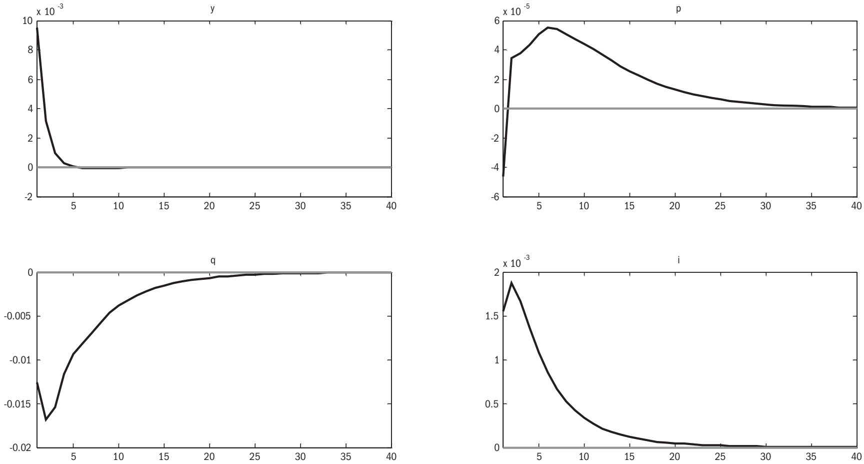
simple and augmented rules). The responses are measured as deviations from the steady-state equilibrium using a second-order Taylor expansion approximation. As such, confidence intervals are not readily available and performing bootstrapping techniques would become a particularly complicated and time consuming exercise, since in each trial we should be able to estimate the model econometrically and then use the estimates to solve the model for its steady state and generate an impulse response path, but neither of these tasks are guaranteed to be successfully completed given the non-linearity and the forward looking features of the model.

Figure 1. Impulse-response functions under simple interest rule

Panel A: orthogonal shock to demand (ε^D)



Panel B: orthogonal shock to supply (ε^S)

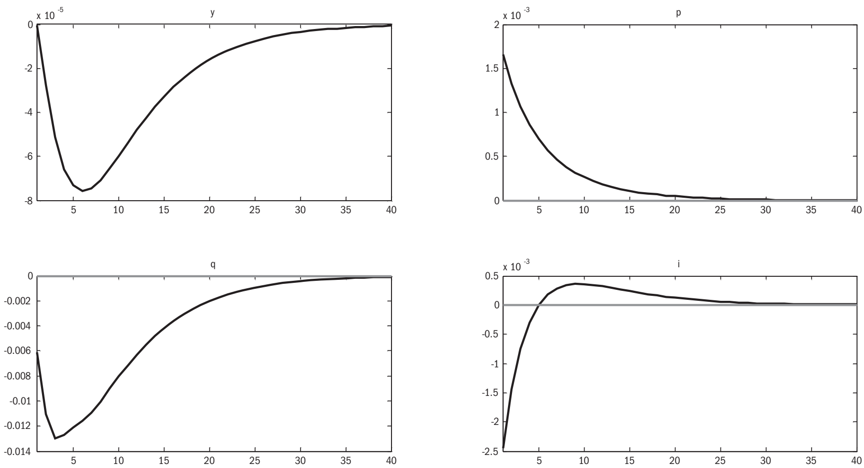


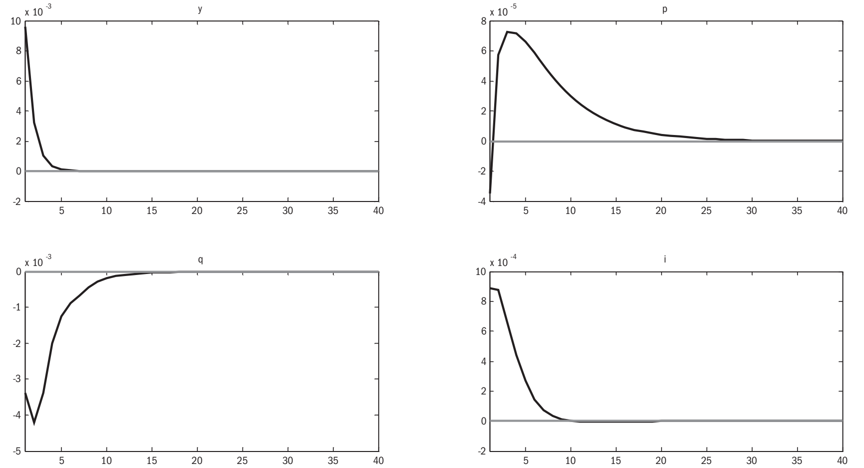
Figure 1, panel B, shows the model's dynamics in response to a negative supply shock under the simple interest rate rule. The shock abruptly increases inflation above steady state in the initial period at the same that it leads to a downturn in economic activity by producing a negative output gap, which goes in hand with an appreciation of the real exchange rate. The optimal response of the central bank is to initially reduce the nominal interest rate but after that to gradually tighten its monetary policy until the interest rate reaches levels above steady state by period ten. After that period, the central bank gradually reduces the interest rate until the economy recovers to its steady state equilibrium. It is important to note that throughout the whole process inflation decays steadily until it goes down to its steady state equilibrium value. The central bank's reaction seems to indicate an initial short-run reaction to contain the negative effects to the real economy (on output and employment derived from the shock) while turning to a restrictive stance once the deepest fall in output is reversed, in order to prevent inflation expectations from rising. In this sense, a concern for the evolution of real variables induces a response from the central bank even in light of an inflationary shock, although the response is temporary to minimize the persistence of the shock. As inflation decays to its steady state equilibrium, it could be argued that the central bank's reaction is appropriate for neutralizing the unexpected shock to underlying inflation.

Figure 2 below presents the impulse-response functions for the model with augmented interest rate rule. By construction, and for comparison, shocks are quantitatively equal than in the previous case. Also, all parameters of the model except for the augmented rule equation are equal in both cases. With regard to the one time demand shock, figure 2, panel A, shows that the responses are similar to the simple case. The initial responses are all qualitatively similar. Quantitatively, the initial response of inflation is similar. However the responses of interest rate and real exchange rate are much more pronounced than in the simple case. In particular, the response of the interest rate is noticeable much higher, reflecting a much more aggressive behavior of the central bank. Consequently, the economy is able to return to its steady state in less time than in the simple interest rule case.

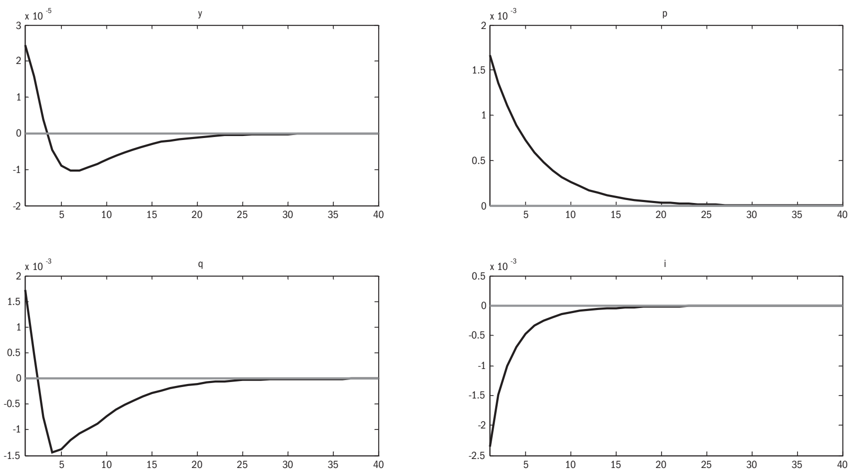
Figure 2, panel B, presents the impulse-response functions for the augmented interest rule model corresponding to a exogenous shock to underlying inflation. Some differences with respect to the simple interest rule case are worth noting. First, initially the economy does not enter to a recession abruptly. The exchange rate initially depreciates. Subsequently, as the exchange rate appreciates, economic activity slows down until the output gap turns negative and reaches its lowest level at period five approximately. After this period the output gap starts to close as the real exchange rate also gradually depreciates. Secondly, the optimal response of the central bank is to initially reduce the interest rate, which is then gradually increased until it comes back to its steady-state level. In this case, there is no need

Figure 2. Impulse-response functions under augmented interest rule

Panel A: orthogonal shock to demand (ε^D)



Panel B: orthogonal shock to supply (ε^S)



for the central bank to increase the interest rate above steady state-level, as in the simple interest rule case. Third, the behavior of the central bank is much more aggressive and more effective than in the simple interest rule case. For example, following a negative supply shock, while the economic downturn takes approximately 40 periods to be eliminated in the simple interest case, it only takes 5 months in the augmented interest rule case. Similarly, while the interest rate takes approximately 30 periods to return to its steady state level in the simple case, it only takes 10 months in the case of the augmented interest rule model. Also, while in the simple interest rule model, the real exchange rate takes approximately 40 months to return to equilibrium following an inflationary shock, it only takes 20 months in the case of the augmented interest rule model.

Overall, the model dynamics under alternative policy rules suggests that the policy rule that takes into account the real exchange rate seems to be more efective to move the economy back to steady-state both in the case of demand and supply shocks, taking less time compared with the simple policy rule, which in turn may imply less costs of adjustment for the economy. This could be an important justification for central banks to take into consideration the real exchange rate in its policy reaction function, particularly in developing economies like Mexico.

VI. Summary and concluding remarks

Monetary policy constitutes a powerful tool which may be used to influence the behavior of aggregate demand. In practice, its conduction is complex and may respond to broad considerations, beyond explicitly stated objectives announced by the central bank. Our results suggest some important points. First, even though monetary policy in Mexico is aimed at controlling inflation, it does not seem to exclusively respond to the behavior of that variable. The central bank seems to assign a positive weight to the behavior of real economic activity when making policy decisions, seeking to maintain output fluctuating around its potential level. Additionally we establish that, the central bank takes into account the behavior of the real exchange rate in its policy reaction function.

Second, the estimation of the simple and augmented rules suggests that the central bank, between 1998 and mid-2008, did establish the conduction of monetary policy as the economy's nominal anchor consistently with the Taylor principle. The finding that key parameters are higher than unity suggests that the central bank's behavior has been sufficiently aggressive in pursuing price stability in the economy. Third, it is seen that for a small open economy like Mexico's, the exchange rate does in fact provide an additional transmission mechanism for monetary policy. The exchange rate responds strongly to changes in monetary policy, inducing both first-round and second-round effects on output and inflation. Fourth, when contrasting the model dynamics under alternative policy rules, we have found that the central bank response to demand and supply shocks seems more effective under the augmented interest rate policy than under the simple, taking less time and possibly being less costly for the economy to return to its steady-state equilibrium.

Finally, using the criteria described in the literature under which optimal monetary policy should operate, results indicate that in Mexico, monetary policy does in fact responded aggressively to aggregate demand as well as aggregate supply shocks. Thus, the interest rate has been effectively used during the past decade to neutralize states of excess demand and also, to eliminate an environment of unemployment-inflation that follows inflationary exogenous shocks. Overall, monetary policy has constituted an effective demand management tool, satisfying this optimality criterion in the case of demand shocks. However, the results suggest that in the case of supply shocks, the nominal interest rate is not kept unchanged. While this response would not be considered optimal in the case of transitory supply shocks, it may be so when inflation is highly persistent and the risk of an inflation-recession environment is latent as is the case in Mexico as well as other economies. This last point merits additional attention in future research on the subject, particularly in the current context of adverse shocks to the economy.

A relevant extension of this paper would consist of verifying the robustness of the estimated parameters to alternative estimation methods. In particular, the recent development of methods which allow for the simultaneous estimation of the system, through the use of Bayesian methods or conditional maximum likelihood, for example, could be useful in the verification of results here obtained. Finally, future research should be aimed at identifying the model's structural parameters, allowing for the evaluation, in terms of welfare, of different policy regimes.

Appendix

Table A1. Stochastic processes for exogenous variables

Non-underlying inflation π_t^{ns}		Nominal wage Δw_t		Fiscal deficit g_t		Nominal exchange rate Δe_t	
c	0.004***	c	0.051	c	-1.639	c	0.002
	(0.001)		(0.056)		(2.688)		(0.002)
π_{t-1}^{ns}	0.343***	Δw_{t-1}	0.362***	g_{t-1}	-0.020	Δe_{t-1}	0.177**
	(0.084)		(0.088)		(0.092)		(0.088)
		Δw_{t-2}	0.186**				
			(0.091)				
		Δw_{t-3}	0.219**				
			(0.092)				
		Δw_{t-4}	0.189**				
			(0.087)				
Adjusted R-squared	0.11		0.86		0.0004		0.024
S.E. of regression	0.0068		0.0204		30.162		0.0186
Durbin-Watson stat	1.9406		2.0281		2.0013		1.9620

Table A2. Foreign variables (VAR)

	π_t	y_t	i_t^*
π_{t-1}	0.295***	0.016	0.043
	(0.089)	(0.169)	(0.090)
π_{t-2}	-0.330***	0.148	0.046
	(0.090)	(0.170)	(0.090)
y_{t-1}	0.012	0.788***	0.062*
	(0.048)	(0.090)	(0.048)
y_{t-2}	0.031	0.075	-0.030
	(0.048)	(0.091)	(0.049)
i_{t-1}^*	0.117	0.515***	1.233***
	(0.090)	(0.170)	(0.090)
i_{t-2}^*	-0.135*	-0.487***	-0.261***
	(0.088)	(0.167)	(0.089)
Adjusted R-squared	0.14	0.83	0.98
S.E. of regression	0.0025	0.0047	0.0025

References

Alesina, Alberto and Andrea Stella (2010), The politics of monetary policy, Working Paper 15856, NBER.

Blanchard, Oliver J. (2008), The state of macro, Working Paper 14259, NBER.

Calvo, Guillermo (1983), Staggered prices in a utility maximizing framework, *Journal of Monetary Economics* **12**: 983-998.

Cermeño, Rodolfo, Bernardo Roth and Alejandro Villagómez (2008), Fiscal policy and national savings in Mexico, 1980-2006, *Estudios Económicos* **23**: 281-312.

Chinn, Menzie. D. (2008), Nonlinearities, business cycles and exchange rates, mimeo, University of Wisconsin.

Clarida, Richard, Jordi Galí, and Mark Gertler (1999), The science of monetary policy, *Journal of Economic Literature* **37**: 1661-1707.

Eichenbaum, Martin, and Charles L. Evans (1995), Some empirical evidence on the effects of shocks to monetary policy on exchange rates, *Quarterly Journal of Economics* **110**: 975-1009.

Favero, Carlo, and Riccardo Rovelli (2002), Macroeconomic stability and the preferences of the Fed: A Formal Analysis, 1961-1998, *Journal of Money, Credit and Banking* **35**: 545-556.

Galí, Jordi, and Tommaso Monacelli (2005), Monetary policy and exchange rate volatility in a small open economy, *Review of Economic Studies* **72**: 707-734.

Galindo, Luis Miguel, and Carlos Guerrero (2003), La regla de Taylor para México: un análisis econométrico, *Investigación Económica* **42**: 149-167.

Lucas Jr., Robert E. (1976), Econometric policy evaluation: A critique, *Carnegie Rochester Conference Series on Public Policy* **1**: 19-46.

Maddala, G. S. (2001), *Introduction to econometrics*, Third Edition, John Wiley & Sons.

McCallum, Benneth, and Edward Nelson (1997), An optimizing IS-LM specification for monetary policy and business cycle analysis, Working Paper 5875. NBER.

Moons, Cindy, Harry Garretsen, Bas van Aarle and Jorge Fornero (2007), Monetary policy in the New-Keynesian Model: An application to the euro area, *Journal of Policy Modeling* **29**: 879-902.

Ramos Francia, Manuel and Alberto Torres (2006), Inflation dynamics in Mexico, A characterization using the New Phillips Curve. Serie Documentos de Investigación 2006-15, Banco de México.

Rodriguez, Gabriel (2006), Stability of central bank preferences, macroeconomic shocks, and efficiency of the monetary policy, empirical evidence for Canada, Working papers 0603E, Department of Economics, University of Ottawa.

Roldán Peña, Jessica (2005), Un análisis de la política monetaria en México bajo el esquema de objetivos de inflación, *Gaceta de Economía* **11**: 119.

Stéphane Adjemian, Houtan Bastani, Michel Juillard, Ferhat Mihoubi, George Perendia, Marco Ratto and Sébastien Villemot (2011), *Dynare: Reference manual, version 4,* Dynare Working Papers 1, CEPREMAP

Svensson, Lars E. O. (2000), Open economy inflation targeting, *Journal of International Economics* **50**: 155-183.

Taylor, Mark, David Peel and Lucio Sarno (2001), Nonlinear mean-reversion in real exchange rates: Toward a solution to the purchasing power parity puzzles, *International Economic Review* **42**: 1015-1042.

Taylor, John (1993), Discretion versus policy rules in practice, *Carnegie-Rochester Conference Series on Public Policy* **39**: 195-214.

Torres, Alberto (2002), Un análisis de las tasas de interés en México a través de la metodología de reglas monetarias, Serie Documentos de Investigación 2002-11, Banco de México.

Wicksell, Kurt (1907), The influence of the rate of interest on prices, *Economic Journal* **17**: 213-220.

Woodford, Michael (2001), The Taylor rule and optimal monetary policy, *American Economic Review* **91**: 232-237.

Woodford, Michael (2007), The case for forecast targeting as a monetary policy strategy, *Journal of Economic Perspectives* **21**: 3-24